CLAIMS

1. A piezoelectric micromotor for moving a moveable element comprising:

a vibrator in the shape of a rectangular parallelepiped formed from a plurality of thin layers of piezoelectric material having first and second identical relatively large rectangular face surfaces defined by long and short edge surfaces wherein the layers are aligned one on top of the other and have their face surfaces bonded together;

electrodes on surfaces of the layers;

a contact region located on one or more edge surfaces of the layers, urged against the body; and

a least one electrical power supply that electrifies electrodes to excite vibrations in the vibrator and thereby in the contact region that impart motion to the body;

wherein at least some of the electrodes are electrifiable to excite transverse vibrations in the vibrator, which transverse vibrations are vibrations parallel to the one or more edges of the layers on which the contact region is situated.

2. A piezoelectric micromotor according to claim 1 wherein the one or more edge surfaces are short edge surfaces of the layers.

Sub. A2

3. A piezoelectric micromotor according to claim 1 or claim 2 and including a wear resistant element situated at the contact region for contact with the body.

4. A piezoelectric micromotor according to any of the preceding claims comprising electrodes on face surfaces of the layers that are electrifiable by an AC voltage provided by the power supply to excite elliptical vibrations in the vibrator having a controllable eccentricity.

5. A piezoelectric micromotor according to any of the preceding claims comprising:

a single large electrode on a first face surface of each layer; and

four quadrant electrodes on a second face surface of each layer wherein the quadrant electrodes are arranged in a checkerboard pattern.

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6. A piezoelectric micromotor according to any of claims 1-3, comprising:

a single large electrode on a first face surface of each layer; and

a single large electrode on the second face surface of at least one but not all layers;

four quadrant electrodes on the second face surface of at least one layer, wherein the quadrant electrodes are arranged in a checkerboard pattern

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7. A piezoelectric micromotor according to claim 5 wherein at least two non-contiguous face surfaces have quadrant electrodes.

8. A piezoelectric micromotor according to claim 5 wherein the at least one power supply electrifies all quadrant electrodes on the second face surface of at least one but not all the layers with a same AC voltage so as to excite longitudinal vibrations in the vibrator and thereby in the contact surface wherein longitudinal vibrations are vibrations parallel to the edges of the layers on which the contact region is situated.

9. A piezoelectric micromotor according to claim 6 wherein the power supply electrifies a large electrode on the second face surface of at least one layer with an AC voltage to excite longitudinal vibrations in the vibrator and thereby in the contact region wherein longitudinal vibrations are vibrations parallel to the edges of the layers on which the contact region is situated.

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10. A piezoelectric micromotor according to claim 8 or claim 9 wherein for at least one layer the at least one power supply electrifies a first pair of diagonally disposed quadrant electrodes with a first AC voltage and a second pair of quadrant electrodes along a second diagonal with a second AC voltage and wherein the first and second AC voltages are 180° out of phase and have a same magnitude, so as to excite transverse vibrations in the piezoelectric vibrator.

11. A piezoelectric motor according to claim 10 wherein the at least one layer comprises a plurality of layers and wherein homologous electrodes on different layers of the plurality of layers are electrified with the same voltage.

Sub A5

12. A piezoelectric motor according to claim 10 or claim 11 wherein the at least one power source controls magnitudes of AC voltages used to excite longitudinal and transverse vibrations to selectively provide different forms and amplitudes of vibratory motion of the contact region in a plane parallel to the planes of the layers.

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13. A piezoelectric motor according to any of claims 10-12 wherein the at least one power source controls phases of AC voltages used to excite longitudinal and transverse vibrations to selectively provide different forms of vibratory motion of the contact region in a plane parallel to the planes of the layers.

Sub A5 cont

14. A piezoelectric motor according to any of claims 10-13 wherein the at least one power source controls frequencies of AC voltages used to excite longitudinal and transverse vibrations to selectively provide different forms of vibratory motion of the contact region in a plane parallel to the planes of the layers.

15. A piezoelectric micromotor according to any of claims 8-14 wherein for at least one layer the at least one power supply electrifies a first pair of electrodes along a first short edge of the layer and a second pair of quadrant electrodes along a second short edge with first and second AC voltages respectively that are 180° out of phase and have a same magnitude, so as to excite bending vibrations perpendicular to the planes of the layers in the piezoelectric vibrator.

16. A piezoelectric motor according to claim 15 wherein the at least one layer comprises a plurality of layers.

17. A piezoelectric motor according to claim 16 wherein homologous electrodes on layers located on a same side of a face surface inside the vibrator are electrified in phase and homologous electrodes on layers located on opposite sides of the face surface are electrified 180° out of phase.

Sub A6

18. A piezoelectric motor according to claim 15 or claim 17 wherein the at least one power source controls magnitudes of AC voltages used to excite longitudinal and bending vibrations to selectively provide different forms and amplitudes of vibratory motion of the contact region in a plane perpendicular to the planes of the layers.

19. A piezoelectric motor according to any of claims 15-18 wherein the at least one power source controls phases of AC voltages used to excite longitudinal and bending vibrations to selectively provide different forms of vibratory motion of the contact region in a plane perpendicular to the planes of the layers.

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Sub A6-cont

20. A piezoelectric motor according to any of claims 15-19 wherein the at least one power source controls frequencies of AC voltages used to excite longitudinal and transverse vibrations to selectively provide different forms of vibratory motion of the contact region in a plane parallel to the planes of the layers.

21. A piezoelectric micromotor according to any of claims 5-20 wherein, for at least one layer, the at least one power supply electrifies a pair of quadrant electrodes that lie along a first diagonal of the layer with an AC voltage while a pair of quadrant electrodes along a second diagonal of the layer are grounded or floating, in order to excite elliptical vibrations in the vibrator.

22. A piezoelectric micromotor according to claim 21 wherein the at least one layer comprises a plurality of layers and wherein homologous electrodes are electrified with the same AC voltage.

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23. A piezoelectric motor according to claim 21 or claim 22 wherein the at least one power supply controls the frequency of the AC voltage to selectively control the eccentricity of the elliptical motion.

24. A piezoelectric micromotor according to any of the preceding claims and comprising at least one relatively thin layer of non-piezoelectric material having large rectangular face surfaces defined by long and short edges and relatively narrow long and short edge surfaces.

25. A piezoelectric micromotor according to claim 24 wherein the one of the edges of the at least one non-piezoelectric layer are substantially equal in length to one of the corresponding edges of the piezoelectric layers.

26. A piezoelectric motor according to claim 25 wherein the one edge is a short edge.

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27. A piezoelectric micromotor according to claim 25 or claim 26 wherein the other edges of the at least one non-piezoelectric layer are slightly longer than the corresponding other edges of the piezoelectric layers so that at least one edge surface of the non-piezoelectric layer protrudes from the piezoelectric layers.

28. A piezoelectric motor according to claim 27 wherein the other edge is the long edge and wherein at least one short edge surface of the non-piezoelectric layer protrudes from the piezoelectric layers.

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29. A piezoelectric micromotor according to claim 27 or claim 28 wherein the contact region comprises a region of one of the at least one protruding edge surface.

30. A piezoelectric micromotor according to any of claims 25-29 wherein the at least one non-piezoelectric layer is formed from a metal.

31. A piezoelectric micromotor according to any of the preceding claims wherein the power supply is capable of electrifying the electrodes to cause motion in a selectively arbitrary direction in the plane of edge surfaces on which the contact surface is located.

32. A method for accelerating or decelerating a moveable body which body is moved by urging a piezoelectric micromotor to the body in a first direction so that a contact region of the piezoelectric motor is pressed to the body and exciting vibrations in the piezoelectric micromotor at the contact region in the first direction and in the direction of motion of the body, said vibrations having a first amplitude in the first direction and a second amplitude in the second direction, the method comprising:

a) for acceleration gradually changing a ratio between the second amplitude relative to the first amplitude from substantially zero to a desired non-zero value; or

b) for deceleration gradually changing the ratio between the second amplitude relative to the first amplitude from a non-zero value to substantially zero.

33. A method according to claim 32 wherein said vibrations in said first direction are excited by providing a first electrification to at least some first electrodes on the piezoelectric motor and wherein said vibrations in said second direction are excited by providing electrification to at least some second electrodes on the piezoelectric motor, at least some of which are different from said first electrodes.

34. A method according to any of claim 33 wherein gradually changing the ratio comprises gradually changing the amplitude of one of the electrifications.

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35. A method according to claim 32 wherein first vibrations in the first and second directions are excited by electrifying at least one first electrode on the piezoelectric vibrator and wherein second vibrations in the first and second directions are excited by electrifying at least one second electrode on the piezoelectric vibrator, wherein the phase of the vibrations in the second direction has substantially a 180^{o} phase difference for the first and second vibrations.

36. A method according to claim 35 wherein for accelerating the body, gradually changing the ratio comprises electrifying both said at least one first electrode and said at least one second electrode to cause cancellation of the vibrations in the second direction and gradually reducing electrification of one of the at least one first electrode and at least one second electrode.

37. A method according to claim 35 wherein for decelerating the body, gradually changing the ratio comprises electrifying only one of said at least one first and second electrodes and gradually changing the ratio comprises gradually increasing electrification of the other of the first and second electrodes to cancel vibrations in the second direction.

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38. A method according to any of claims 33 - 37 wherein the piezoelectric motor comprises at least one piezoelectric layer and wherein the first and second electrodes are on the same layer.

39. A method according to any of claims 33 - 37 wherein the piezoelectric motor comprises a plurality of piezoelectric layers and wherein the first and second electrodes are on different layers.

40. A method according to claim 32 wherein vibrations in the first direction are excited by applying a voltage to the piezoelectric motor within a first frequency range and wherein vibrations in the second direction are excited by applying a voltage to the piezoelectric motor within a second frequency range which partially overlaps the first frequency range.

41. A method according to claim 40 wherein for accelerating the body gradually changing the ratio comprises comprises applying a voltage at a frequency at which vibrations in

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substantially only the first direction are excited and changing the frequency of the voltage to a frequency at which both vibrations in the first and second vibrations are excited.

42. A method according to claim 40 wherein for decelerating the body gradually changing the ratio comprises applying a voltage at a frequency at which both vibrations in the first and second directions are excited and changing the frequency of the voltage to a frequency at which vibrations in substantially only the first direction are excited.

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